

6. Decommissioning

This section describes the consideration of life-cycle environmental factors in the discontinuation, disassembly, decontamination, storage, and disposal of systems, processes, and facilities⁴.

6.1 Products and Systems

Most life cycle engineering efforts will be directed at the development or modification of products and systems at the beginning of their life cycle. However, there are numerous systems in place that could benefit from application of an LCE perspective during their retirement and final disposition. In many cases the process and consequences of decommissioning were not considered during the original design engineering effort. LCE of the recovery, disassembly, materials and component recycling activities under these circumstances is less than optimal, but still potentially benefits from application of life cycle thinking.

6.2 Processes and Facilities⁵

Decommissioning of processes and facilities involves a series of steps that can include investigation of technology applicability, pilot or preliminary-scale demonstrations, and application of the technology. The latter includes the life cycle aspects of input materials for cleaning, dismantlement, and final disposition or recycling along with the associated environmental burdens of each activity. An additional source of guidance on the application of LCE for site remediation may be found in Diamond et al. (1999) and Page et al. (1999).

6.3 LCE Case Study: Pantex Facility Decommissioning

The Department of Energy's Pantex Plant is currently in the process of decontaminating structures no longer needed to support its new mission. These structures may include production, administrative or testing facilities. Decommissioning of production and test facilities has the complication of the possibility of mixed – hazardous and radioactive – contamination. Pantex desires to reduce the radioactive decontamination levels of such facilities to *de minimis* levels, which allows for a much larger number of disposal or recycling options. Further, Pantex personnel wish to promote and use more environmentally benign decontamination methods whenever possible. This led to testing of two competing technologies for decontamination of surfaces — Steel Grit Blasting and Crushed Safety Glass Blasting.

⁴ This type of decision is separate and distinct from the end-of-life stage that is considered as one of the life cycle stages of products, systems, processes, and facilities.

⁵ Facility decommissioning may also extend to site remediation that likewise involves a series of decisions regarding materials and resources use and efficiency, costs, and technical performance.

6.3.1 Targeting the Assessment

Establishing the Function Being Provided

The basis of performance comparison between the two decontamination technology systems was removal of one $\mu\text{Ci-sq.ft.}$ (There are 2.22×10^6 dpm per μCi , and 0.0000929 ft^2 per 100 cm^2 .)

Naming the Evaluation Team

The evaluation team for these competing technologies consisted of:

Battelle Life Cycle Management personnel who provided expert LCA skills,

Pantex Plant E, H & S personnel, and

The Team Leader from the technology demonstration contractor who provided expert knowledge on the practices and operation of the technologies.

Developing Requirements and Goals

The purpose of the technology demonstration was to evaluate the potential for either or both of the technologies to satisfactorily decontaminate a radioactively contaminated surface so that the materials could be disposed of or recycled via the standard solid waste management system. The LCA was performed to provide additional information over and above simple performance, and was to supplement the projected cost and performance data collected on site with estimates of overall life cycle environmental burdens. These burdens included a number of standard environmental impacts such as resource consumption, greenhouse gas emissions, and release of toxicants to air, water and solid waste streams.

Proposing Engineering Technology Options

Two alternative technologies were evaluated.

Both technologies make use of materials reclaimed from the waste stream. Each is a media blasting technology, similar to sand blasting, and as such, are optimal for the removal of surface contamination. The prime difference between the systems lies in the blasting media. The Crushed Safety Glass Blasting makes use of safety glass reclaimed from automobiles, trucks, and other sources. The glass is crushed and sorted to size. The steel grit used is slag, a by-product of steel manufacture. The steel grit is also crushed and sorted by size.

The technology in general consists of a large air supply, a hopper that contains blasting media, and a handheld delivery device. In order to minimize wind drift of the spent media and removed material, a small rectangular enclosure measuring about 18 inches on each side was built around the handheld unit. To this unit a vacuum hose was attached. A constant vacuum was applied to the enclosure to capture as much of the fine particulate matter removed material as possible. This stream was passed through a HEPA filter, which served to capture the fine particulate matter, prior to discharge to the atmosphere.

6.3.2 Preliminary Assessment

Defining the Life Cycle

The life cycle for the competing technologies was defined to include all activities from collection of geologic resources, production of virgin materials, collection and processing of the reclaimed or recycled materials, application during the demonstration, through clean up and disposal of

residual materials. Transportation of materials was included where required, as was the manufacture, use and disposal of personal protective equipment.

6.3.3 Detailed Assessment

The LCI showed that glass media blasting technology was far superior to the steel grit blast technology from an environmental standpoint. The assessment showed an almost across the board factor of 5.7 times less environmental burdens for the glass media blasting compared to the same criteria for steel grit blasting. Examination of the results by life cycle stage showed that the factor could be directly attributed to the difference in energy consumption in production of the materials required to effect an equivalent radiation removal.

At the same time that the environmental profile clearly identified the glass media blast technology as the preferred alternative, the performance assessment data were less than satisfactory. Given the objective to remove the contamination to a level that would allow the disposal as solid waste, neither technology proved adequate. This finding points out the need in most LCE evaluations for at least one of the alternatives to meet the performance objectives. Upon realizing that the blasting options would not work a third option to cut up the contaminated surfaces into smaller pieces that could be handled as radioactive waste was implemented.

6.4 LCE Case Study: GBU-24 Weapon System Decommissioning

The LCED Energetic Materials Project includes a LCA, which also considers cost and performance, on two DoD weapon systems which use cyclotrimethylenetrinitramine Research Development Explosive (RDX): the GBU-24 earth penetrator and the M-900 projectile. The GBU-24 is a one-ton earth penetrator conventional explosive bomb used by both the US Navy and Air Force. The assembled bomb includes a BLU-109 bomb body filled with PBXN-109 energetic material, an FMU-143 fuse, and a guidance system. PBXN-109 contains RDX in the form of Coated Explosive Material Number 7 (CXM-7), aluminum powder, and various binders and additives. The M-900 is an APFSDS-T cartridge used for the 105 mm gun employed on the M1 Abrams tank. The cartridge is equipped with a depleted uranium penetrator section designed for a muzzle velocity of 1,500 meters per second. The M-900 is made up of a steel case and sabot, depleted uranium penetrator rod, M43 propellant, and a fuse.

6.4.1 Targeting the Assessment

Establishing the Function Being Provided

The functional unit for the assessment was one GBU-24 unit. Each is designed to penetrate up to 6 feet in reinforced concrete.

Naming the Evaluation Team

The evaluation team for this effort consisted of management and technical functions. Members of the team included:

- Battelle Memorial Institute Life Cycle Management staff who are experts in Life Cycle Assessment, and
- Operations personnel at Los Alamos National Laboratory and Holston Army Ammunition Plant.

These groups interacted on a number of occasions. Operations personnel provided inventory data in the form of reports. Battelle assembled the inventory data and provided the impact assessment.

Developing Requirements and Goals

The requirement of the design activity was to guide the improvement of the UPM-880 by improving upon eleven impact metrics relating inventory inputs and outputs to: photochemical smog formation, ozone depletion, acid rain, global warming, eutrophication, carcinogenicity, human inhalation toxicity, wildlife toxicity, fish toxicity, land use, and resource depletion. Requirements were differentiated from goals using the Analytical Hierarchy Process (AHP) as a group exercise by Battelle staff to reflect DoD policy and local site perspective. The team was asked to reach consensus on weighting factors grouped into global, regional and local applicability.

Proposing Engineering Technology Options

Initially, assessments focused on two energetic product streams:

- ◆ PBNX-109 explosive in the GBU-24 earth penetrator bomb, and
- ◆ M43 propellant in the M-900 armor-penetrating fin-stabilized desheathing sabot.

6.4.2 Preliminary Assessment

Defining the Life Cycle

Modules included in the inventory included:

- geologic and biotic resource extraction (bauxite, coal, iron ore, limestone, natural gas, petroleum),
- Intermediate materials manufacturing (acetic acid, acetone, ammonia, binders, cyclohexanone, dioctyladipate, formaldehyde, hexamine, propyl acetate, trichloroethane, and triphenyl phosphate),
- PBNX-109 synthesis performed at the Holston Army Ammunition Plant (HSAAP) in Kingsport, Tennessee,
- Load, assemble, and pack operations for the GBU-24 performed at the McAlester Army Ammunition Plant (MCAAP) in McAlester, Oklahoma,
- The M43 propellant production at the Indian Head Naval Surface Warfare Center in Indian Head, Maryland (the focus of a separate LCA),
- Demilitarization, and
- Transportation and electricity generation.

6.4.3 Detailed Assessment

Table 6.1 presents the results of the detailed assessment of the GBU. Inventory data were not available to support the determination of contribution to ozone depletion, water use, resource extraction, or land use.

Table 6.1 Detailed Assessment Results

Option	Environmental Characteristics
PBNX-109 Explosive	♦ Coal is the resource material most heavily used in the life cycle.
	♦ Energy requirements for the life cycle are met by fuels using electricity generation, steam generation for motive power and process heating, and transportation.
	♦ Trichloroethane, a hazardous liquid, used for solvent soak operations in DEMIL is the largest DoD facility waste followed by solid residuals from coal-based steam generation plants. Airborne releases are largest for sulfur dioxides, acetic acid, and nitrogen oxides.
	♦ The carcinogenicity environmental impact category shows the greatest normalized impact score when all impacts assessed are assigned equal importance. The carcinogenicity and terrestrial toxicity impact categories contribute 46% and 41% respectively of the total normalized impact scores.
	♦ For a national “policy focused” perspective, carcinogenicity contributes 46% and terrestrial toxicity contributes 38% of the total weighted impact scores. For a “local focused” perspective, carcinogenicity contributes 47% and terrestrial toxicity contributes 39% of the total weighted impact scores.
M43 propellant	♦ Major sources of waste from M43 production include isopropyl shipping fluids, working solvents used in propellant processing, and to a lesser extent, waste propellant.

6.4.4 Developing Specifications

Since the carcinogenicity and terrestrial toxicity impact categories contribute the most to the total impact of the baseline process, the emissions in these categories were considered as a place to focus improvement activities. It was found that the assessment of potential impacts suggested a different plan of action than a “less-is-better” evaluation of the inventory information.